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Necessity of biodiesel utilization as a source of renewable energy in Malaysia

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ABSTRACT

In recent decades, the energy crisis and environmental issues have become a crucial problem. The rapid industrialization has lead humankind to deplete the fossil fuels and consequently the pollutant emissions have increased in the world. Many investigations have been done to find an alternative fuel to fulfill increasing energy demand. Recently, biodiesel has been introduced as an economical renewable and sustainable fuel which is cited as an environment-friendly resource. Around 350 oil-bearing crops were analyzed and some of them were capable to be considered as potential alternative fuels for diesel engines. These include virgin vegetable oils and waste vegetable oils. Rapeseed, jatropha, soybean, and palm oil are mentioned as the most common sources of biodiesel. Many countries have invested in biodiesel as an acceptable source of energy not only in research area but also in production and export. It has been proven that the biodiesel combustion characteristics are similar as petroleum. Higher ignition pressure and temperature, shorter ignition delay and higher peak release were reported in experimental combustion of biodiesel blends. Also, the efficiency of biodiesel base catalysts is more than enzymes and acid catalysts. This article is a literature review on necessity of biodiesel production as alternative fuel recourse in Malaysia and tries to illustrate the combustion characteristics and pollutant formation in biodiesel application.

Contents

1. Introduction

Energy consumption is increasing rapidly due to progress in the standards of living. Nowadays, the fossil fuels play crucial role in the transportation, industrial development and agricultural sectors. However, petroleum resources are limited and depleting day by day. Furthermore, environmental problems are the most important consequences of more fossil fuel consumption. In order to cope with these vital problems biodiesel has lately received more attention because of its enormous resources in the world and environmental friendly characteristics [1]. Biodiesel is defined as fatty acid methyl or ethyl esters from animal fats or vegetable oils [2]. Biofuels are gained from renewable energy recourses and it has been proven that they are non-polluting; however fossil fuels are mentioned as non-renewable energy and pollutant fuels [3]. Generally, biofuel represents all of gaseous and liquid fuels mainly extracted from biomass. For example biodiesel, biomethanol, bioethanol and biohydrogen are extracted from biofuel [4]. The privileges of biodiesel not only have

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convinced governments to take biodiesel in account as an energy resource but also have pursued them to take new strategies to expand biodiesel production. Statistics illustrate that biodiesel production has risen drastically in recent years. Figs. 1 and 2 depict world annual ethanol and biodiesel production from 2005 to 2020 respectively according to OECD and FAO Secretariats [5].

Some countries like Canada and the US, France, Brazil, India, Indonesia, Malaysia and Australia are cited as the main producers of biodiesel [5].

Some prominent strategies have been planned to augment biodiesel contribution in fuel cycle by various countries as such [6–10]:

- From 2005 to 2010 ethanol production raised 40% in Brazil. Using 20–25% anhydrous ethanol with petrol and minimum blending of 5% biodiesel (B5) by end of 2010 are other plans was sketched for Brazil.
- The target of Canadian energy program was application of 5% renewable component in petrol by 2010 and 2% renewable content in diesel by 2012.
- The target which was assigned for European Union by European Commission in January 2008 and UK is 10% and 5% biofuel application in the year 2020 respectively.
- Three percent ethanol blend in petroleum and 2.5% of biodiesel blend in diesel were the Indonesia strategies in biodiesel area by 2010.

In Malaysia recently more focus is observed in quality of biodiesel export rather than application inside country.

2. Biodiesel production in Malaysia

Malaysia is located in South East Asia and has a tropical weather. The temperature is uniform in Malaysia throughout the year due to its equatorial climate. The average rainfall reported is 200–250 cm per year [11]. These exclusive circumstances have prepared excellent conditions for effective photosynthesis. Therefore, biofuel can be the best energy source for countries like Malaysia, which have huge jungles and their

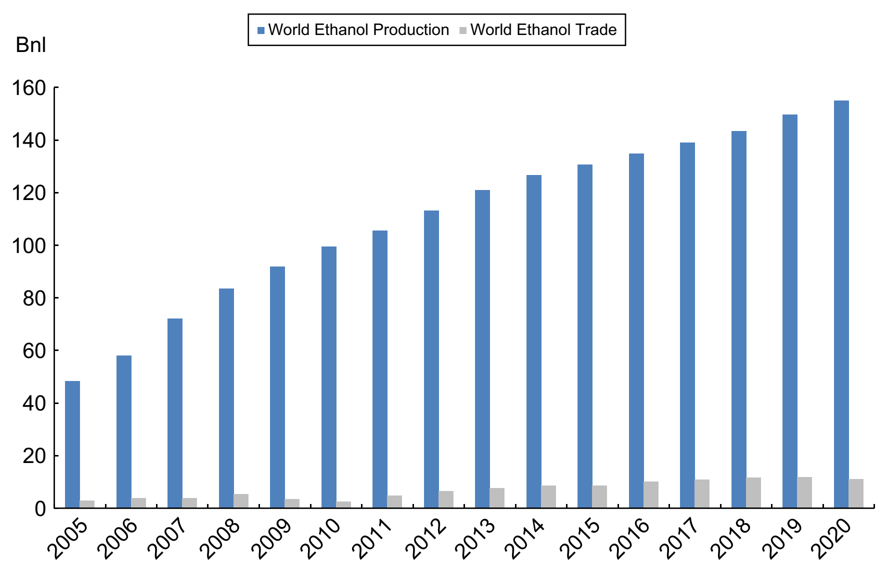

Fig. 1. World annual ethanol production.

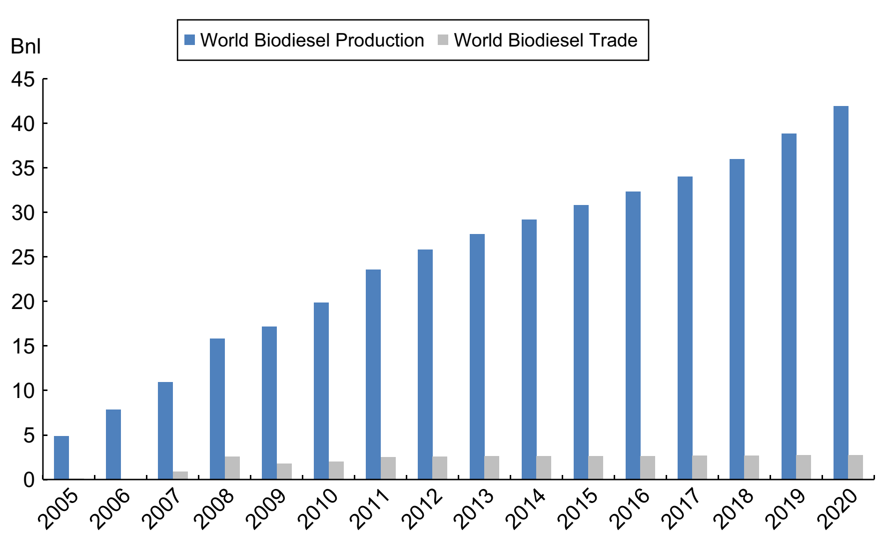

Fig. 2. World annual biodiesel production.

Table 1
Biomass resources and their estimated energy potential in Malaysia [13].

Type of industry	Production (Mton)	Type of biomass	Residue generated (Mton)	Calorific value of biomass(Kj/Kg)	Potential energy generated (Mton)[a]
Oil palm	59.8c	Empty fruit bunches	12.30c	18,838a,b	5.53
		Fronds and trunk	21.10a	–	–
		Fiber	8.75c	19,068a,b	3.99
		Shell	3.94c	20,108a,b	1.89
Paddy	2.14c	Palm kernel	2.11a	18,900a,b	95
		Rice husk	0.47c	15,324e	0.17
		Rice straw	0.86c	13,620f	0.28
Sugar	1.11c	Bagasse	0.36c	8021g	0.069
Wood	1.67d	Sawdust	0.96d	19,008–19,188h	0.44
	0.3d	Plywood residue	0.069d	10,000–19,000i	0.024
Municipal solid waste	11940 t/d	Municipal solid waste	–	9500j	–

[a] Potential energy generated (ton)=residue generated (ton) is 1000 Kg × calorific value (Kj/Kg)/41868000 Kj.

Table 2
Energy demand in Malaysia 2000–2010.

Source	Petajoules			Average annual growth rate	
	2000	2005	2010	8 MP (%)	9 MP (%)
Industrial	477.6(38.4%)	630.7(38.6%)	859.9(38.8%)	5.70	6.40
Transport	505.5(40.6%)	6613(40.5%)	911.7(41.1%)	5.50	6.60
Residential and commercial	162.0(13.0%)	213.0(13.1%)	284.9(12.8%)	5.60	6.00
Non-energy	94.2(7.6%)	118.7(7.3%)	144.7(6.5%)	4.70	4.00
Agriculture and forestry	4.4(0.4%)	8.0(0.5%)	16.7(0.8%)	12.90	15.90
Total	1243.7(100%)	1613.7(100%)	2217.9(100%)	5.60	6.30

Table 3
Energy supply by source in Malaysia 2000–2010.

Source	Petajoules			Average annual growth rate	
	2000	2005	2010	8 MP (%)	9 MP (%)
Crude oil and petroleum products	988.1(49.3%)	1181.2(46.8%)	1400.0(44.7%)	3.60	3.50
Natural gas	845.6(42.2%)	1043.9(41.3%)	1300.0(41.6%)	4.30	4.50
Coal and coke	104.1(5.2%)	230.0(9.1%)	350.0(11.2%)	17.20	8.80
Hydro	65.3(3.3%)	71.0(2.8%)	77.7(2.5%)	1.70	1.80
Total	2003.1(100%)	2526.1(100%)	3127.7(100%)	4.70	4.40

economics is based on agriculture [12]. Table 1 depicts biomass resources and their estimated energy potential in Malaysia [13].

Statistics have confirmed that Malaysia would get into trouble soon due to fossil fuel shortages as it is estimated to get over during next 40 years. Tables 2 and 3 illustrate the rate of energy demand and energy supply from 2000 to 2010 in Malaysia [14].

A lot of subsidies have been paid by the Malaysian Government to keep the cost of petroleum fixed especially in transportation due to global increasing fossil fuel price. In order to overcome these terrible conditions the Malaysian Government has been looking for alternative fuels as fossil fuel substitution [15]. Palm oil is obtained from palm tree, and it can be grown easily in Malaysia. Palm trees in Malaysia are originated from West Africa [16]. Malaysia designed a palm diesel program in the 1980s. The Malaysians Palm Oil Board (MPOB) has cooperated with PETRONAS to develop a special biodiesel generation based on palm oil. In 2008, the Malaysian Government reported that around US$ 20,000 million is obtained by palm oil export [17]. Malaysia is mentioned as one of the largest biodiesel producer countries which uses palm oil as feedstock [18]. Around 73% of total agriculture harvests are palm oil in Malaysia [19]. Also 42.3% of worldwide palm oil production and 48.3% of world's palm oil export is dedicated to Malaysia [20]. It has been proven that palm oil has very intensive capability to be applied as a source of renewable energy, and Fig. 3 shows the potential sources of renewable energy from palm oil.

Biodiesel based on palm oil production was programmed from 1982 to reach the use of B5 (5% palm oil and 95% diesel) blend for Malaysian industries and vehicles [21]. National biofuel policies which have been taken by the Malaysian Government have lead this country to apply biofuel for transportation, industrial sectors and export. Also biofuel technology should be spread for a clean environment according to these policies. Undoubtedly, by implementing these valuable strategies fossil fuels dependency decreases and palm oil demand promotes. Therefore, several benefits are obtained by the Malaysian Government [18].

Furthermore, according to the United Nations Climate Change Conference (UNFCCC) in Copenhagen in 2009, Malaysia as a developed country has pledged to decline 40% of its CO_2 pollutant by 2020 compared to the year 2005. By applying biodiesel (blending of 5% biodiesel and 95% mineral diesel) carbon emission reduction is expected. In order to achieve this important issue the National Biofuel Policy (NBP) was formed in 2005 [22]. The most important policies of NBP were palm oil promotion as a biofuel in

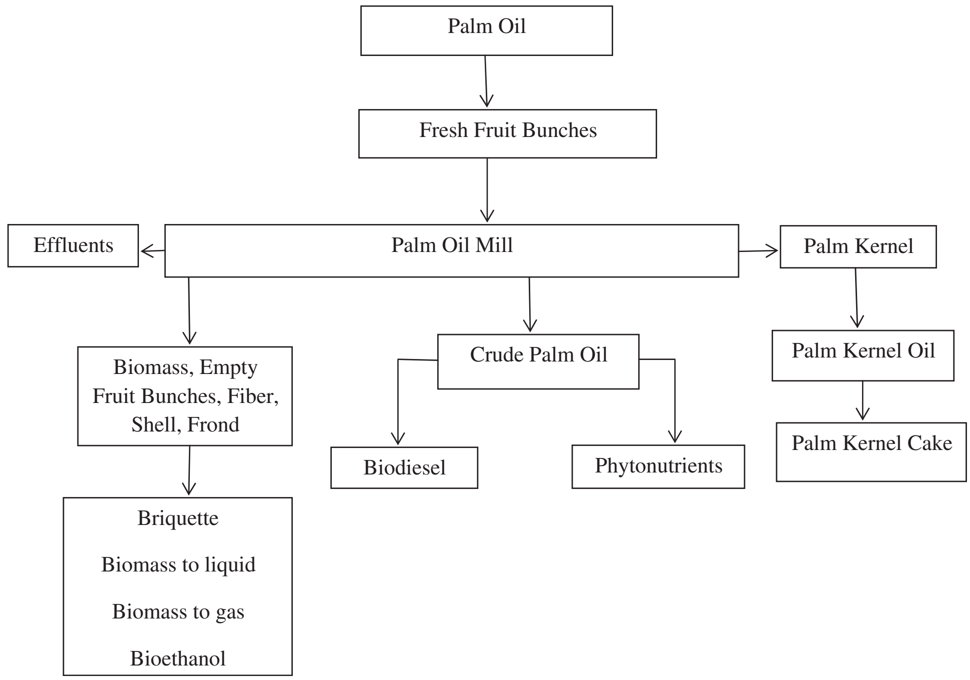

Fig. 3. The potential sources of renewable energy from palm oil.

Table 4
Global energy consumption by sectors.

Sector	1973		2008	
	Mtoe	Share (%)	Mtoe	Share (%)
Industry	1544.6	33.00	2345.1	27.80
Transport	1081.2	23.10	2299.4	27.30
Agricultural/commerce/civil	1764.6	37.70	3036.9	36.00
Non-energy use	285.3	6.10	747.1	8.90
Total	4675.7	100	8428.5	100

order to substitute conventional fuels [23]. Palm oil is used for heat production in different applications in Malaysia. For instance, palm oil is used in timber drying, charcoal production and electricity generation extensively [24]. However, in recent years the main application of palm oil is to be converted into biofuels, which can be applied as a fuel for transportation. This alternative fuel not only declines transportation fuel price but also reduces greenhouse gas pollutant. Malaysia which has become the world leader palm oil producer reduces its fossil fuel dependency and preserves the environment and improves economy [17]. Transportation and industrial factories are mentioned as the main energy users in Malaysia by 40.3% and 38.6% respectively, and the demand of energy is expected to rise at a rate of 5–7% per year during the next 20 years from 2004 [25].

3. Application of biodiesel in transportation and industrial sectors in Malaysia

Transportation plays crucial role in globalization and economy. Majority of energy consumption has been dedicated to transportation sectors that not only depletes non-renewable energy sources but also creates negative effects to the environment. Global climate change is an inevitable consequence of emissions production from fossil fuel combustion in vehicles engine [26]. NO_x and CO_2 which are named as greenhouse gases (GHG) are vital in global climate changing. Statistics show about 13.5% of global warming is generated by transportation [27]. Table 4 [28] illustrates the rate of energy consumption in various industrial sectors from 1973 to 2008. The rate of energy consumption by transportation sectors increased from 1081 Mtone (23.1%) in 1973 to 2300 Mtone (27.3%) in 2008.

More than 40% of energy consumption was dedicated to the transportation system in Malaysia in the year 2000. Although energy demand for Malaysian industrial sectors have surpassed recently, considerable part of energy consumption has been allocated to transportation [29,30].

Fatty acid methyl ester (FAME) or biodiesel is produced through transesterification of vegetable oils with methanol in presence of suitable catalysts. FAME is cited as the best substitute of diesel in compression–ignition (CI) engine without needing any engine modification [22]. One of the most promising products from palm oil is palm methyl ester (PME) which is named as the best alternative fuel for diesel fuel due to its similar characteristics to petroleum [31]. Some investigators have applied PME as a fuel in diesel engine and have reported excellent combustion performance [32–37]. In contrast, it is reported that high pour point is the biggest foible of PME as a fuel for engine [38]. Although experimental results depict higher blend of biodiesel has better performance, the main target for Malaysian industrial sectors is applying B5 diesel in their boilers, generators and machinery at this moment. In this important issue all of the industrial sectors are taken in account. For instance, biodiesel is considered as a good alternative fuel in marine industry because many boaters have reported that the rate of smoke decline due to non-toxic and biodegradable characteristic of biodiesel [39].

4. Biodiesel production process

The life time of engine usually decreases by applying crude palm oil in engine due to carbon deposits inside the engine because of the high boiling point and high viscosity of palm oil. Furthermore, in these conditions plugging and gumming of filters, pipe lines and injectors are inevitable due to the presence of natural gums (phosphatides) in palm oil. By converting vegetable

Table 5
Structural formula, melting and boiling points for fatty acids.

Fatty acid	No.of carbons and double bonds	Chemical structure	Melting point (deg. C)	Boilng pont (deg. C)
Caprylic	C8	CH(CH2)6COOH	16.5	239
Capric	C10	CH3(CH2)8COOH	31.3	269
Lauric	C12	CH3(CH2)10COOH	43.6	304
Myristic	C14	CH3(CH2)12COOH	58	332
Palmitic	C16:0	CH3(CH2)14COOH	62.9	349
Palmitoleic	C16:1	CH3(CH2)5CH=CH(CH2)7COOH	33	–
Stearic	C18:0	CH3(CH2)16COOH	69.9	371
Oleic	C18:1	CH3(CH2)7CH=CH(CH2)7COOH	16.3	–
Linoleic	C18:2	CH3(CH2)4CH=CHCH2CH=CH(CH2)7COOH	−5	–
Linoleic	C18:3	CH3(CH2)2CH=CHCH2CH=CHCH2CH+CH(CH2)7COOH	−11	–
Arachidic	C20:0	CH3(CH2)18COOH	75.2	–
Eicosenoic	C20:1	CH3(CH2)7CH=CH(CH2)9COOH	23	–
Behenic	C22:0	CH3(CH2)20COOH	80	–
Eurcic	C22:1	CH3(CH2)7CH=CH(CH2)11COOH	34	–

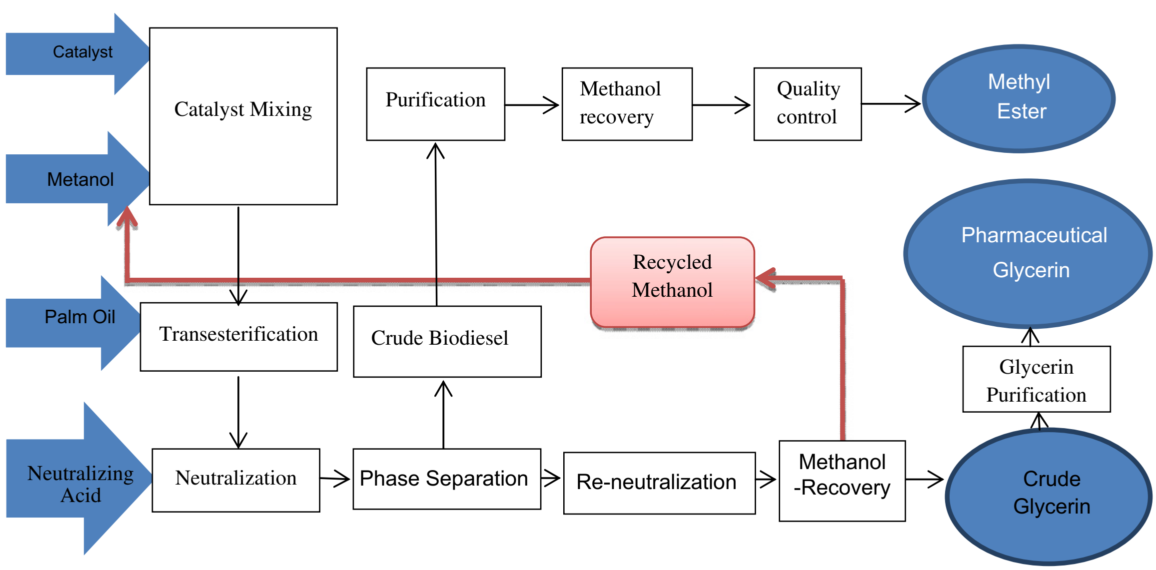

Fig. 4. Biodiesel production process.

oils such as palm oil into biodiesel (methyl or ethyl esters) a complete combustion is reachable. Additionally, the heating value of biodiesel is lightly higher than vegetable oil. The common method to convert vegetable oil into biodiesel is transesterification reaction. Transesterification is a chemical reaction between palm oil and alcohol (methanol or ethanol) in presence of a strong catalyst (KOH, NaOH or H_2SO_4) [120].

Table 5 illustrates the names, boiling point and melting point of some common fatty acids. It is noteworthy that vegetable oils are usually a combination of several fatty acids, therefore the properties of these fatty acids play curtail role in chemical characteristics of vegetable oil and biodiesel extracted from them. Palm oil is used as the most important raw material in biodiesel production in Malaysia. The root of palm oil's name is palmitoletic acid (16 carbon saturated acid) which is found in palm oil chemical structure.

The basic routes for biodiesel production from palm oil are:

- Catalyzed transesterification of the palm oil.
- Direct acid catalyzed transesterification of the palm oil.
- Converting the palm oil to its fatty acid and then to biodiesel.

The most economical method for biodiesel production is catalyzed transesterification due to its low temperature, low pressure and high efficiency. A triglyceride contains a glycerin molecule with three long chain fatty acids attached. The properties of the fat are determined by the fatty acids nature attached to the glycerin. In the esterification process, the triglyceride reacts with alcohol in the presence of a catalyst, usually a strong alkali like sodium hydroxide. The reaction between alcohol and fatty acids constitutes biodiesel or the mono-alkyl ester, and crude glycerol. Methanol or ethanol are used as the alcohol in the biodiesel production (methanol produces methyl esters, ethanol produces ethyl esters) and the base catalyzed can be either potassium or sodium hydroxide. It has been reported that potassium hydroxide is more suitable for the biodiesel production process. Fig. 4 depicts a biodiesel production plan process in Malaysia [121].

5. Combustion characteristics of biodiesel

Solar energy which is stored in biomass as chemical energy during photosynthesis can be released through combustion. Oxygen content is the main difference between biofuels and fossil fuels. The combustion efficiency in biofuel is more than petroleum due to their higher oxygen content [13]. The characteristics of vegetable oil combustion in compressing ignition engine has

been experimented by many researchers recently [40–47]. Sulphur, which is mentioned as the effective parameter in acid rain formation, does not exist in vegetable oils. Furthermore, the rate of corrosion in crankcase oil decreases in the absence of sulphur. Some researchers have investigated the diesel engine durability by applying pure vegetable oil [48,49]. Low volatility and high viscosity are reported as the main detrimental characteristics of vegetable oils, and several problems happen during their application in compression ignition (CI) engine due to these disadvantages. Therefore, vegetable oils should be converted to biodiesel in order to eliminate the detrimental properties for applying in CI engine [50]. Ignition delay, spray penetration and ignition temperature are the most important characteristics of various biodiesel that have been experimented. Biodiesel whether pure or in blend type can change the fuel ignition form [51]. Brake thermal efficiency in biodiesel is more than fossil fuel due to combustion improvement. The power of engine is slightly lower than the system fueled by biodiesel because more biodiesel should be consumed to compensate its low calorific value specification. Totally, acceptable performance is reported in biodiesel combustion process [52]. The following recommends have been published by investigators in Malaysia, Germany and USA about adaptation of diesel generators fueled with biodiesel based palm oil [53]:

- The viscosity of vegetable oil is higher than diesel oil in the same temperature, therefore poor atomization in injectors is expected.
- Injection system should be tasted and cleaned after around 150 h operation.
- 3 mm filter should be applied to collect probable contaminants.
- Copper pipes can react with palm oil at temperature around 508 °C. Therefore application of copper pipes is not recommended in high temperature.
- Petroleum should be applied to start and warm up the engine.

6. Biodiesel combustion emissions

One of the key items behind biofuel spread policy is climate change. According to the Kyoto Protocol (KP) in 1997 industrial countries should reduce the pollutants by at least 5% below 1990 levels [54]. However, none of the Asian countries are listed in KP as Annex. 1 countries. This means that they were not obliged to decline their greenhouse gas pollutants as they are still developing. Climate change is mentioned just by Malaysia [18]. Many experiments have been done to evaluate the various blends of biodiesel combustion emissions. It has been proven that carbon dioxide, carbon monoxide, sulphur oxides, particulate matter, oxides of nitrogen and smoke are the main pollutants which are formed by biodiesel combustion. The most important emissions from biodiesel combustion are debated in this section.

6.1. NO_x (Nitrogen oxides)

The rate of NO_x production has become a controversial topic in pollutant formation of biodiesel combustion. Some researchers have reported a declination in NO_x formation during diesel engine operation by biodiesel [55–65]. However the majority of the authors have published a rise in NO_x emission as their experimental evidence [66–84]. Few literatures have emphasized on NO_x formation similarity in fossil fuel and biodiesel [85,86]. These differences in the result are predominantly related to their various experimental conditions, engine type, its operating systems and biodiesel content, but some strategies are suggested to decline NO_x production in biodiesel. Increasing the injection fuel pressure and postponing the injection timing are the main applicable ways to reduce NO_x formation [87]. Szybist et al. [51] stipulated applying cetane number improver additives could be the very solution to NO_x declination. Pradeep and Sharma [88] applied exhaust gas recirculation (EGR) method to decrease NO_x formation for Jatropha feedstock. Indeed, some kinds of additives such as alcohol (ethanol and methanol) [72,89,90], metal base additives [91–93], emulsifiers and cetane number improver [81,94] were suggested to NO_x formation declination.

6.2. CO_2

Since CO_2 is a greenhouse gas and plays a great role in global warming phenomenon, study about the rate of CO_2 formation from biodiesel combustion has become prominent. Some authors studied CO_2 formation due to significant contribution percent (around 23%) of CO_2 emission in biodiesel combustion [95]. It is claimed that the CO_2 production from biodiesel combustion is recycled by plans due to CO_2 effects on oilseed growing which is applied as biodiesel based in transesterification, therefore CO_2 production from biodiesel burning declines significantly compared with diesel combustion [96]. In contrast, some investigators published results illustrating that the rate of CO_2 increases in biodiesel combustion [97–99]. Some other researchers claimed inconspicuous alteration in CO_2 formation [100].

6.3. Particulate matter (PM)

Application of biodiesel in engine systems instead of petroleum promises a declination in PM formation. It has been reported the rate of PM production decreases about 50% for biodiesel in compared to diesel [101–108]. Some researchers have claimed that there is no difference between biodiesel and diesel PM emissions [109,110], while others reported some increase in PM emissions due to higher viscosity of biodiesel [111–113]. Generally, it has been proven that PM emission declines drastically with increasing in biodiesel content in blends [114].

6.4. CO (Carbon monoxide)

Predominantly, it is reported that the rate of CO formation declines in biodiesel combustion because of its higher oxygen and lower rate of carbon to hydrogen compared to diesel [115–118]. It has been proven that CO emission decreases if the content of biofuel is raised [119]. Keskin et al. [92] emphasized on the role of metal based additive on CO declination in biodiesel combustion. Also, application of additive alcohols like methanol and ethanol in biodiesel can decrease CO formation [75].

7. Conclusion

The problem of depleting fossil fuel recourses and the raising awareness of environmental pollution from petroleum combustion illustrate the necessity of finding renewable alternative fuels for petroleum substitution. The most important privileges of vegetable oils in comparison with petroleum are their renewability and environmental friendly characteristics. Comprehensive studies have confirmed that Malaysia can be assessed as one of the important poles of biofuel and possesses a good prospect for biodiesel production. Numerous jungles of palm trees can be seen in Malaysia due to their compatibility with tropical weather. Palm base biodiesel is more desirable than other biodiesel feedstock because its oxidation stability is more than others. Economy is in progress in Malaysia rapidly and economic growth dependency to

energy consumption is undeniable. Therefore, energy consumption augment is expected 6–8% annually in Malaysia. Unfortunately, nonrenewable recourses such as petroleum, natural gas, crude oil and coal still dominate the Malaysia energy sectors. Non-renewable resources not only release a large amount of greenhouse gases to the environment but are also depleting day by day and these facts increase the necessity of displacing non-renewable energy with renewable energy in the near future. The implementation of new strategies and various programs have confirmed that the importance of renewable energy has been identified for the Government of Malaysia. Obviously, Malaysia can be one of the great biodiesel contributors in the world via palm oil. Indeed, more researches should be done to discover biodiesel specification and intensify the knowledge in combustion and pollutant formation areas. For example in biodiesel pollution investigation the situation of NO_x and PM emission is not obvious. Although, many researches have been done in biodiesel combustion and its pollutant evaluation, the characteristics of biodiesel emission especially in NO_x and PM pollutant are not clarified. Majority of investigators have mentioned the NO_x augment as the biodiesel weak point. Investment in investigation about palm oil production, biodiesel improvement, obtaining more efficiency in combustion and energy conversion and environmental issues are the most important strategies that should be taken by the Government of Malaysia.

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